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ULTRASONIC PULSE VELOCITY (UPV) TEST ON CONCRETE UNDER COMPRESSION: A STUDY ON EFFECT OF ASPECT RATIO

Chai Peng How

Bachelor of Engineering with Honours
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ULTRASONIC PULSE VELOCITY (UPV) TEST ON CONCRETE UNDER COMPRESSION: A STUDY ON EFFECT OF ASPECT RATIO

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This project is submitted in partial fulfilment of the requirement for the degree of Bachelor of Engineering with Honours (Civil Engineering)

Faculty of Engineering
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Dedicated to my family and beloved one

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ABSTRACT

This project describes a research study on the effect of aspects ratio in concrete at different levels of compressive stress on the measured of ultrasonic pulse velocity (UPV) values. Concrete prisms with grade 25 and 30 with different height/width ratio were used and tests were carried out at 28 days. The test results for concrete prisms of grade 25 and 30 showed similar trends. However, the changes of UPV values in concrete prisms of grade 30 are more significant than concrete prisms of grade 25. It was also found that the compressive stress in concrete have more significant effect of the measured UPV values on concrete prisms with aspect ratio of 1:1, which is the smallest height/width ratio. In general, the UPV values increased in concrete prisms at stress-strength ratio ranging from 0 to 0.25. After which, the measured UPV values reduced significantly under a higher compressive stress of up to 0.5 stress-strength ratio. When subjected to compressive stress which corresponds to a stress-strength ratio of 0.25, the UPV values increased by about 4.7% to 5.7% for concrete prisms with aspect ratio 1:1 of grades 25 and 30 respectively. After which, the measured UPV values reduced significantly under a higher compressive stress of up to 0.5 stress-strength ratio, with a reduction of about 6.9% to 7.3% for concrete prisms with aspect ratio 1:1 of grades 25 and 30 respectively at the age of 28 days. These results show that compressive stress in concrete has significant effect on the measured UPV values. This implies that the state of stress in concrete has to be determined first when UPV

is used for the estimation of in-situ concrete strength. Otherwise, if in-situ UPV values are used to estimate the in-situ concrete strength by using the correlated results based on stress-free concrete in the laboratory, the in-situ concrete strength may be underestimated, in particular if the state of stress is more than 0.25 stress-strength ratio.

ABSTRAK

Projek ini merupakan penyelidikan mengenai kesan dari segi nisbah dalam konkrit pada tahap tegasan mampatan yang berlainan dengan menggunakan "Ultrasonic Pulse Velocity" (UPV). Prisma konkrit pada gred 25 dan 30 dengan nisbah ketinggian kepada lebar yang berlainan telah digunakan. Eksperiman ini dijalankan apabila konkrit sample mencapai hari ke-28. Keputusan bagi prisma konkrit gred 25 dan 30 adalah serupa pada hari ke-28. Walau bagaimanapun, perubahan nilai UPV dalam konkrit gred 30 adalah lebih besar dibandingkan dengan konkrit gred 25. Didapati bahawa tegasan mampatan dalam konkrit mempunyai kesan yang lebih mendalam terhadap nilai UPV bagi prisma konkrit yang mempunyai nisbah 1:1, iaitu nisbah ketinggian kepada lebar yang paling kecil. Secara umumnya, nilai bagi UPV meningkat apabila kadar tegasan-kekuatan berada dalam kekuatan 0 hingga 0.25. dan seterusnya menurun lebih mendadak apabila kadar tegasan-kekuatan ditingkatkan sehingga 0.50. Apabila prisma konkrit berada dalam kadar tegasan-kekuatan sehingga 0.25, nilai UPV meningkat kira-kira 4.7% hingga 5.7% bagi prisma konkrit dengan nisbah 1:1 gred 25 dan 30 masing-masing. Seterusnya, nilai UPV menurun mendadak apabila kadar tegasan-kekuatan ditingkatkan sehingga 0.5, iaitu menurun kira-kira 6.9% hingga 7.3% bagi prisma konkrit dengan nisbah 1:1 gred 25 dan 30 masing-masing. Keputusan eksperimen ini menunjukkan bahawa tahap tegasan mampatan dalam konkrit mempunyai kesan yang mendalam terhadap nilai UPV. Ini menunjukkan bahawa

kadar tegasan mampatan perlu ditentukan apabila nilai UPV digunakan untuk menganggar kekuatan konkrit pada insitu. Sekiranya tidak, nilai UPV yang digunakan untuk menganggar kekuatan konkrit pada insitu akan menjadi kurang jika keputusan UPV yang setaraf digunakan dalam keadaan tanpa tegasan mampatan di dalam makmal, terutamanya apabila kadar tegasan-kekuatan adalah lebih daripada 0.25.

TABLE OF CONTENTS

CONTENTS **PAGE**

ACKNOWLEDGEMENTS			i
ABSTRACT			ii
ABSTRAK			iv
TABLE OF CONTENTS			vi
LIST OF TABLES			ix
LIST OF FIGURES			x
LIST OF SYMBOLS			xi
Chapter 1	**INTRODUCTION**		
	1.1	General	1
	1.2	Problem Statement	3
	1.3	Objective of the Research	4
	1.4	Scope of Work	5
	1.5	Organization of the thesis	5

Chapter 2	**LITERATURE REVIEW**		
	2.1	General	6
	2.2	Ultrasonic Pulse Velocity (UPV) Test	6
	2.3	The Compressive Strength of Concrete	9
	2.4	Size Effect of the Compressive Strength of Concrete	10
	2.5	Ultrasonic Pulse Velocity to the Compressive Strength of Concrete	12
	2.6	The Effects of Age On Ultrasonic Pulse Velocity in Concrete	15
	2.7	The Effect of Steel-bar Reinforcement on Ultrasonic Pulse Velocity in Concrete	17
	2.8	The Effect of the Mix Ratio on Ultrasonic Pulse Velocity in Concrete	19
	2.9	The Effects of Compressive Stress on Ultrasonic Pulse Velocity in Concrete	20
	2.10	Summary	20
Chapter 3	**METHOLODOGY**		
	3.1	General	22
	3.2	Ultrasonic Pulse Velocity Method	22
	3.3	Portable Ultrasonic Non-destructive Digital Indicating Tester (PUNDIT)	27

3.4 Test Load Frame 29

3.5 Test Procedure

3.5.1 Mix of Concrete 30

3.5.2 Test Programme 31

Chapter 4 RESULTS AND DISCUSSION

4.1 General 33

4.2 Effect of Aspect Ratio on UPV Values

4.2.1 Grade 25 Concrete at 28 Days 34

4.2.2 Grade 30 Concrete at 28 Days 38

4.3 Summary 40

Chapter 5 CONCLUSION 45

REFERENCES 47

APPENDIXES 49

LIST OF TABLES

Table		Page
3.1	Concrete mix proportion by weight of cement	30
3.2	Concrete prism test specimen	32
4.1	Average measured concrete strength and measured UPV of test cubes under stress free condition	34
4.2	Changes in ultrasonic pulse velocity for grade 25 concrete at the age of 28 days	35
4.3	Changes in ultrasonic pulse velocity for grade 30 concrete at the age of 28 days	38

LIST OF FIGURES

Figure		Page
1.1	The Portable Ultrasonic Nondestructive Digital Indicating Tester (PUNDIT)	2
2.1	Relationshipbeteen pulse velocity and crushing srenght for concrete: A = Ruppert and Hesse: B = Elvery; C = Davis and Robertson. (Vold and Hope, 1978)	13
2.2	Variation of strength and pulse velocity with age of concrete	16
2.3	Ultrasonic propagation in reinforced concrete in the direction parallel to the steel bars: a = perpendicular distance from the axis of the direct ultrasonic beam from the nearest steel bar b; I =distance between the probe (BS 1881, 1986, Part 203)	18
3.1	Types of transducer arrangement (a) Direct Transmission, (b) Semi Direct Transmission & (c) Indirect Transmission	25
4.1	Effect of Compressive Stress on the Ultrasonic Pulse Velocity of Concrete Prisms for Grade 25 at 28 Days	43
4.2	Effect of Compressive Stress on the Ultrasonic Pulse Velocity of Concrete Prisms for Grade 30 at the 28 Days	44

LIST OF SYMBOLS

L	-	Path length
t	-	Time travel by ultrasonic pulse
V	-	Velocity of ultrasound in concrete
Ed	-	Elastic modulus
p	-	Density of material
μ	-	Poisson's ratio
a	-	Perpendicular distance from the axis of the direct ultrasonic beam from the nearest steel bar
c , c_s	-	The respective speeds in concrete and steel
l	-	Distance between the probes
A	-	The volume fractions of coarse aggregate in a concrete sample
B	-	The volume fractions of fine aggregate in a concrete sample
$c_{A,}$	-	The speeds of ultrasound in coarse aggregate
c_B	-	The speeds of ultrasound in fine aggregate
c_P	-	The speeds of ultrasound cement

CHAPTER 1

INTRODUCTION

1.1 General

The standard method of evaluating the quality of concrete is to test specimens casted simultaneously for compressive, flexural and tensile strengths. According to Felman (1977), since there can be no direct measurement of the strength properties of structural concrete for the simple reason that strength determination involves destructive stresses, several non- destructive methods of assessment has been developed. These depend on the fact that certain physical properties of concrete can be related to strength and can be measured by non-destructive methods. Such properties include hardness, resistance to penetration by projectiles, rebound capacity and ability to transmit ultrasonic pulses and X- and Y-rays.

At present the ultrasonic pulse velocity method (BS 1881: Part 203), is the only one of this type that shows potential for testing concrete strength in-situ.

According to Norsuzailina (2003), the Ultrasonic Pulse Velocity (UPV) is a non-destructive technique involving the measurement of the speed of ultrasound through materials in order to predict material strength, calculating low-strain elastic modulus and/or detecting the presence of internal flaws such as cracking, voids, honeycomb, decay and other damage. This technique is applicable where intrusive (destructive) testing is not desirable and can be applied to concrete, ceramics, stone and timber. The main strength of this method is in finding general changes in condition such as areas of weak concrete in a generally sound structure. Absolute measurements should be treated with caution.

Norsuzailina (2003) concluded that the measurement of the velocity of ultrasonic pulses as a mean of testing materials was originally developed for assessing the quality and condition of concrete. The Portable Ultrasonic Nondestructive Digital Indicating Tester (PUNDIT) will undoubtedly be used predominantly for this purpose. Figure 1.1 shows the PUNDIT equipment.

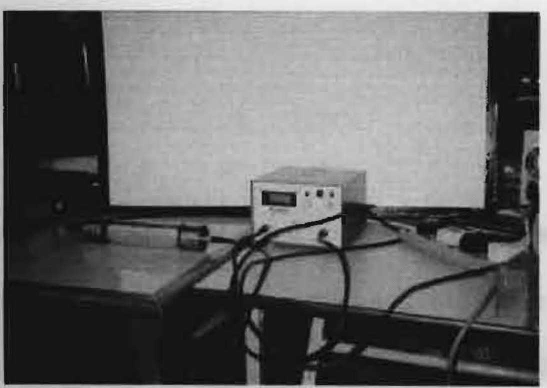

Figure 1.1: The Portable Ultrasonic Nondestructive Digital Indicating Tester (PUNDIT)

The UPV test measures the velocity of a high-frequency ultrasonic pulse passing through a concrete member between two transducers; with a high velocity taken to reflect a high density and hence a better quality of concrete. M.G.Hernandez (2000) stated that high pulse velocity readings are generally indicative of good quality concrete. Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of structural concrete to be predicted within ± 20 %, provided the types of aggregate and mix proportions are constant.

In summary, ultrasonic pulse velocity tests have great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. They are excellent, also, for determining relative strengths of concrete in different parts of the same structure. If properly used, they can provide a very important link in the chain of testing and evaluating concrete and concrete structures.

1.2 Problem Statement

The ultrasonic pulse velocity test can be carried out on both laboratory-sized specimens and completed concrete structures, but some factors affect the measurement. According to Ng and Ngu (2004), all existing structures are subjected to some kind of stresses. Most columns are solely under compression. Flexural stresses occur in beams. If the UPV test is to be used to evaluate any in-situ concrete strength, the UPV values of the concrete under stressed condition are measured. This is followed by taking the concrete cores for strength evaluation in the laboratory. Before the concrete cores are tested for compressive strength, they are usually measured for their UPV values under stress-free condition. These measured UPV values are normally correlated with the compressive strength of concrete cores taken from the existing structures. Therefore, the UPV values of stress-free concrete are correlated with the concrete strength in the laboratory. This correlation is then used to evaluate the in-situ concrete strength by comparing the measured in-situ UPV values of the stressed concrete to the correlated results. This may be erroneous as concrete under different level of stresses may result in different measured UPV values.

Previous tests were only carried out on cubes for the effect of compressive stress of concrete on UPV (Ng and Ngu 2004). Concrete prisms with different aspect ratio was also carried out but loaded to low stress-strength ratio of 0.1 (Tan 2004). The effect of end-restraint has not been studied sufficiently to demonstrate its effect for concrete under compressive stress. Therefore, this study is conducted to study effect of aspect ratio for higher stress-strength ratio.

1.3 Objectives of the Research

This project describes a research study on the effect of aspect ratio of concrete prisms on the measured ultrasonic pulse velocity (UPV) values of concrete under compressive stress. The limit of aspect ratio affecting the effect of end-restraint will be identified.

1.4 Scope of Work

The scope of work in this study includes preparing concrete prisms for the compressive strength tests. Concrete prisms with aspect ratio ranging from 1.0 to 5.0 are casted and tested under compressive stresses which correspond to stress-strength ratio from 0.1 to 0.5 with direct measurement of UPV value using Portable Ultrasonic Nondestructive Digital Indicating Tester (PUNDIT) is carried out for concrete prisms under compression at 28 days.

1.5 Organization of the Thesis

This research is presented in a five chapters. The First Chapter gives an introduction to the topic and the scope of work, while the Second Chapter is on the literature review of related works. Chapter Three covers the testing procedure and testing materials, whereas Chapter Four comprises the experimental results and discussion. Chapter Five presents conclusions drawn from the experimental results along with the recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 General

This chapter describes a review on ultrasonic pulse velocity test (UPV), the compressive strength of concrete, and the size effect to the compressive strength of concrete. Together with this, the effect of the compressive strength of concrete, the effect of age, the effect of the steel-bar reinforcement, and the effect of the mix ratio to UPV values are described. Some previous works on the effect of compressive stress on ultrasonic pulse velocity of concrete are also discussed.

2.2 Ultrasonic Pulse Velocity Test

Ultrasonic pulse velocity test is an established nondestructive test method which measures the time taken for a pulse of longitudinal waves traveling through a measured distance (Neville 1995). Therefore, the ultrasonic pulse velocity (UPV) is measured; thus the name of the method. The ultrasonic pulse velocity correlated with the measured concrete strength can be used to evaluate the in-situ concrete strength. However, the correlation is always carried out by measurement of UPV values of concrete under stress-free condition in the laboratory (Ng and Ngu 2004). The applications of this UPV test include measurements of composition, strength, homogeneity, elastic modulus and age, together with the detection of the presence of defects. An account of early work in this field is given by Jones (1962) and information regarding current practice can be obtained from the appropriate standards such as BS 1881 (1986) Parts 203 and 201.

Ultrasonic waves or stress waves are utilized in the measurement of ultrasonic pulse velocity (UPV) in order to evaluate the concrete quality in structures. Unlike other forms of electromagnetic radiation, which can travel freely through vacuum, ultrasonic waves can only exist within mass media. The waves are transmitted from one mass to another by direct and intimate contact between the masses.

The measurement of ultrasonic pulse velocity requires apparatus that include a transmitting transducer and receiving transducer. The apparatus generates a pulse of the vibrations at an ultrasonic frequency which are transmitted by the transmitting transducer held in contact with the surface of the concrete under test. After passing through the concrete, the vibrations are received and converted to an electrical signal by the receiving transducer to transmit ultrasonic waves (frequency ranging from 10 to 150 kHz is used for testing of concrete) directly through concrete specimen. It measures the path length and time of travel of an ultrasonic pulse passing through the concrete. Generally a denser material will have faster velocity. With the path length (L) and the time travel (t) an ultrasonic pulse obtained using the instrument and hence the Ultrasonic Pulse Velocity (UPV) in the specimen can be calculated by the following equation:

$$UPV = L / t \tag{2.1}$$

The ultrasonic pulse velocity tests can be carried out on both laboratory-sized specimens and completed concrete structures. There must be smooth contact with the surface under test; a coupling medium such as a thin film of oil is mandatory. It is desirable for path-lengths to be at least 12 in. (30 cm) in order to avoid any errors introduced by heterogeneity. It must be recognized that there is an increase in pulse velocity at below-freezing temperature owing to freezing of water; from 5 to 30°C (41 - 86°F) pulse velocities are not temperature dependent. It is an ideal tool for establishing whether concrete is uniform. Usually, if large differences in pulse velocity are found within a structure for no apparent reason, there is strong reason to presume that defective or deteriorated concrete is present.

High pulse velocity readings are generally indicative of good quality concrete. Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of structural concrete to be predicted within ±20 %, provided the types of aggregate and mix proportions are constant.